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Systematics and Conservation Status of *Claytonia lanceolata* var. *flava* (Portulacaceae)

J. STEPHEN SHELLY[1]

Montana Natural Heritage Program,
1515 East 6th Avenue, Helena, Montana 59620

PETER LESICA

Division of Biological Sciences,
University of Montana, Missoula, Montana 59812

PAUL G. WOLF[2], PAMELA S. SOLTIS, and DOUGLAS E. SOLTIS

Department of Botany, Washington State University,
Pullman, Washington 99164

[1]Present address: Wildlife, Fisheries and Botany Unit,
U. S. Forest Service, P.O. Box 7669,
Missoula, Montana 59807

[2]Present address: Department of Biology,
Utah State University, Logan, Utah 84321

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ABSTRACT

A systematic study of *Claytonia lanceolata* and related taxa in the Rocky Mountains was conducted. The study was specifically undertaken to evaluate the taxonomic status of *C. lanceolata* var. *flava*, as part of an assessment to determine the need for protection of the latter taxon under the federal Endangered Species Act. Electrophoretic and morphological studies revealed that populations of *C. lanceolata* var. *flava* in southwestern Montana and northwestern Wyoming represent a diploid (*n*=8) species whose populations consist of yellow- and/or white-flowered plants. This taxon does not belong in the *C. lanceolata* complex, but is best placed in the group of narrow-leaved species that includes *C. rosea*, *C. tuberosa* and *C. virginica*. Numerous populations, most often consisting of the white-flowered phenotype, were found in Montana and Wyoming, and legal protection is not warranted at this time. In some cases, actions to conserve endangered plant taxa must be preceded by an evaluation of their taxonomic status; this study illustrates the utility of modern systematic techniques in conducting such evaluations.

INTRODUCTION

Claytonia lanceolata Pursh (Portulacaceae) is a common, wide-ranging species of western North America (Hitchcock et

al. 1964). *Claytonia lanceolata* var. *flava* (A. Nels.) C. L. Hitchc. has been applied to yellow-flowered populations in the northern Rocky Mountains (Davis 1966; Hitchcock et al. 1964). This unique variant was first collected in 1899 in Fremont County, Idaho (Nelson 1900). From 1911 to 1988, it was additionally collected at five stations in southwestern Montana (Shelly 1989) and one station in northwestern Wyoming (Marriott 1986). It was rediscovered at the type locality in 1986 (D. Atwood, pers. comm.). The infrequency of collection and the relatively restricted geographic range of these yellow-flowered populations led to the designation of *C. lanceolata* var. *flava* as a candidate for possible listing under the federal Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1985).

As part of an evaluation to determine the need for such protective listing, we undertook a study to assess the placement of *C. lanceolata* var. *flava* in that species, using isozyme electrophoresis and morphological comparisons with the common, white- to pink-flowered *C. lanceolata* var. *lanceolata*. Initial field surveys of known populations of *C. lanceolata* var. *flava* revealed the presence of narrow-leaved, white-flowered plants that were morphologically very similar to the yellow-flowered individuals, and which did not fit the descriptions of typically broader-leaved *C. lanceolata* var. *lanceolata*. Thus, we also examined the degree of isozyme differentiation between white- and yellow-

flowered individuals of these narrow-leaved plants, and whether any other morpological differences aside from petal color exist between them. Yellow- and white-flowered individuals of the narrow-leaved plants are biotically sympatric in four of the study locations, and C. lanceolata var. lanceolata is biotically or neighboringly sympatric with the narrow-leaved plants in five of the study locations. Other closely related taxa included in this study were C. lanceolata var. chrysantha (Greene) C. L. Hitchc., C. lanceolata var. multiscapa (Rydb.) C. L. Hitchc. and C. rosea Rydb.

TAXONOMIC HISTORY

The first collection of a yellow-flowered Claytonia in the northern Rocky Mountains was made in 1899 by Aven and Elias Nelson (5488, RM), near the northwest corner of Henry's Lake in Fremont County, Idaho. It was subsequently described as C. aurea (Nelson 1900). Interestingly, Rydberg (1922) reduced this name to a synonym of C. chrysantha Greene (= C. lanceolata var. chrysantha (Greene) C. L. Hitchc., a yellow-flowered form of the latter species occurring in western Washington (Douglas and Taylor 1972)), undoubtedly based on the shared flower color. Claytonia aurea was later renamed C. flava, the former name having already been used by Kuntze in 1891 (Nelson 1926). Since that time, Claytonia flava has been reduced to a variety of C. lanceolata on two separate occasions, first by Hitchcock et al. (1964), and then by Davis (1966). The latter revision was perhaps in ignorance

of the Hitchcock treatment, and Davis is occasionally cited as the author of this change. More recently, the taxon has again been treated as a full species (Dorn 1984).

The taxonomy of Claytonia is currently being revised for the Flora of North America project (Miller 1992). Pending publication of this treatment, throughout this paper the name C. lanceolata var. flava will be used to discuss populations of both the white and yellow flower color phenotypes of the taxon, except when citing previous alternate treatments.

MATERIALS AND METHODS

Five populations of C. lanceolata var. lanceolata and seven populations of C. lanceolata var. flava (including five of the yellow-flowered phenotype and seven of the white-flowered phenotype) were sampled for field morphological studies and isozyme electrophoretic studies. In most cases, the same populations of each taxon or color phenotype were sampled for both studies. The study populations are located in southwestern Montana and northwestern Wyoming (Fig. 1, Table 1).

I. Morphological Studies

Field and herbarium morphological studies were conducted. We emphasized characters that are easily examined on living plants and pressed specimens, and that have been used in past keys treating some or all of the taxa of interest.

In the field, morphological data were collected from 720 living plants, representing five populations of C. lanceolata var. lanceolata and eleven populations of C. lanceolata var. flava (five yellow-flowered and six white-flowered populations). In each population, 45 randomly chosen plants were examined for the following characters: stem height, leaf length and width, petal length and width, and sepal length. Stem height was measured in centimeters, from ground level to the point of attachment of the uppermost pedicel; all other lengths were measured in millimeters. For the computer analyses, the length/width ratios of the leaves and petals were also calculated.

In addition to the field studies, 184 herbarium collections, representing C. lanceolata vars. lanceolata, flava, multiscapa, and chrysantha, as well as C. rosea, were examined from the following herbaria: MONTU, OSC, RM, UA, UAL, WSU, WTU (CHECK). In addition to the characters listed above, petal apex outline and cauline leaf venation were scored for the herbarium specimens (see Table 6 for scoring criteria).

II. Isozyme Electrophoresis

A total of 679 individuals, representing 15 populations (five of C. lanceolata var. lanceolata and five for each flower color phenotype of C. lanceolata var. flava), were sampled. Whole flowering stems, including the cauline leaves, were collected by clipping the plants at ground

level. These were kept chilled in the field for one to several days until placement in ultracold storage (-80°C).

Leaves were ground immediately upon removal from the ultracold freezer, in the Tris HCl-PVP crushing buffer of Soltis et al. (1983). Sixteen loci, representing ten enzymes, were resolved using three electrophoretic buffers. A morpholine buffer (pH 6.4; Ordzykoski and Gottlieb 1984) was used to resolve glyceraldehyde-3-phosphate dehydrogenase (G3PDH), malate dehydrogenase (MDH), and phosphoglucomutase (PGM). Buffer 8 of Soltis et al. (1983) was used to resolve alcohol dehydrogenase (ADH), aspartate aminotransferase (AAT), leucine aminopeptidase (LAP), phosphoglucoisomerase (PGI), and triosephosphate isomerase (TPI). Buffer 11 of Soltis et al. (1983) was used to resolve isocitrate dehydrogenase (IDH) and 6-phosphogluconate dehydrogenase (6PGD). The stain recipe for ADH was that described by Wendel and Weeden (1989). All other staining protocols were those described by Soltis et al. (1983).

III. Data Analysis

We assessed the morphological distinctiveness of the various taxa using principal components analysis (PCA) and discriminant analysis. These analyses were performed using SYSTAT (Wilkinson 1986), and were based on the characters listed above.

Electrophoretic data were analyzed using the computer program BIOSYS-1 (Swofford and Selander 1981). Three separate analyses were performed: 1.) allele frequencies at 16 loci were entered for all 15 populations and analyzed for genetic variability statistics and Nei's genetic identity among populations; 2.) allele frequencies at 16 loci were entered for the ten C. lanceolata var. flava populations (including yellow- and white-flowered phenotypes) and analyzed for Nei's genetic identity among populations; and 3.) eight C. lanceolata var. flava populations, from all localities except Hebgen Lake (all yellow-flowered) and Boulder (all white-flowered), were entered as genotype numbers and analyzed for population substructuring, to examine differences between color phenotypes within localities. An unweighted pair group method (UPGMA) was used for cluster analysis of Nei's genetic identity relationships.

RESULTS

I. Morphological Studies

1. Field Studies. Taxon means, ranges, and standard deviations for the eight quantitative characters measured on living plants are given in Table 2.

According to the loadings given in Table 3, petal width, leaf length, stem height, leaf length/width ratio, sepal length, and petal length/width ratio made significant contributions to the first principal component. Characters

contributing most to the second principal component included leaf width and petal length. The PCA of the field morphology data revealed that allopatric populations containing either narrow-leaved (C. lanceolata var. flava) or broad-leaved (C. lanceolata var. lanceolata) plants are more similar to each other than are neighboringly sympatric populations of differing leaf morphology (Fig. 2). Aside from flower color, the yellow- and white-flowered individuals of C. lanceolata var. flava are highly similar morphologically, and are well-distinguished from C. lanceolata var. lanceolata by the differences in leaf and petal shape (Fig. 2, Table 2).

In a discriminant analysis comparing the white- and yellow-flowered individuals of C. lanceolata var. flava, the cross-validation error rate for the discriminant function was 0.42; there is only a 58% chance of correctly identifying the two flower color phenotypes of C. lanceolata var. flava based on the morphological characters used in the analysis. Thus, the two phenotypes cannot be reliably discriminated on characters other than flower color.

2. **Herbarium Studies.** Taxon means, ranges, and standard deviations for the eight quantitative and two qualitative characters examined on the herbarium collections are given in Table 4.

Leaf venation, petal apex outline, leaf length/width ratio, leaf width, petal/sepal length ratio, and sepal length were the characters contributing most to the first principal component (Table 5). Petal width and length contributed significantly to the second principal component. The PCA of the herbarium morphological data indicated that *Claytonia rosea* and *C. lanceolata* vars. *flava* and *multiscapa* are all morphologically distinct from *C. lanceolata* var. *lanceolata*, and are very similar to one another (Fig. 3).

II. Isozyme Electrophoresis

Each isozyme was treated as a genetic locus and each allozyme as an allele. Coding of populations of *C. lanceolata* var. *flava* was straightforward, as simple diploid expression was observed in all of them. However, *C. lanceolata* var. *lanceolata* expressed more complex tetraploid banding patterns. In order to make comparisons among varieties and flower color phenotypes at each locality, it was necessary to code allele frequencies for *C. lanceolata* var. *lanceolata*. This was done by assuming that each individual was tetraploid and possessed four doses of allozymes (alleles). Some individuals, therefore, expressed more than two alleles at a locus. Relative staining intensities were used to determine dosage effects (Wolf 1988). Allele frequencies are given in Table 6.

1. Differences between varieties. A UPGMA cluster analysis of Nei's genetic identity values is shown in Fig.

4. Owing to allelic differences between them, all 5 populations of C. lanceolata var. lanceolata were completely separated from the ten populations of C. lanceolata var. flava (represented by samples of both white- and yellow-flowered plants). The mean genetic identity between populations of these two taxa was 0.69 (WILL NEED TO REVISE THIS).

2. Differences among populations of C. lanceolata var. flava. The UPGMA cluster analysis also indicates the level of differentiation among populations, either yellow- or white-flowered, of C. lanceolata var. flava (Fig. 4). Genetic identity values among the six localities ranged from 0.870 (Boulder [all white-flowered plants] compared to Hebgen [yellow-flowered]) to 0.989 (Anaconda [white-flowered] compared to Champion [both yellow and white phenotypes]). The genetic identities correspond to geographic proximity; the Hebgen Lake and Wyoming populations clustered together, as did the Anaconda, Champion, and Vipond populations farther to the northwest in Montana. The Boulder population is the most genetically distinct of the ten diploid C. lanceolata var. flava populations sampled; the mean genetic identity of this population to the other nine is 0.895.

3. Differences between color phenotypes within populations of C. lanceolata var. flava. In the four cases where they

are biotically sympatric, yellow- and white-flowered "populations" of C. lanceolata var. flava were more similar to each other than to allopatric populations of the same flower color (Fig. 4). The Nei's genetic identity values between color phenotypes within localities were high, ranging from 0.995 (Vipond Park) to 1.00 (Anaconda) (Table 7).

DISCUSSION

Morphological studies and isozyme electrophoresis first revealed that C. lanceolata var. flava represents a distinct diploid species (2n = 16; Marriott 1986), wholly different from C. lanceolata var. lanceolata (which, as discussed above, displayed tetraploid banding patterns in the populations sampled). In past treatments petal color, described as "golden yellow" by Davis (1952, 1966) and "deep yellowish-orange" by Hitchcock et al. (1964), was the primary character used to distinguish C. lanceolata var. flava from related taxa at the level of species (as C. flava; Davis 1952) or variety (Davis 1966, Hitchcock et al. 1964). However, PCAs of our morphological data indicated that the characters most important for distinguishing C. lanceolata var. flava from typical C. lanceolata are related to leaf morphology (length/width ratio and venation) and petal shape (length/width ratio and apex outline).

Davis (1952) described the leaves of C. lanceolata var. flava as "linear or lance-linear," as compared to "stem

leaves lanceolate" in C. lanceolata. Similarly, Hitchcock et al. (1964) described the stem leaves of C. lanceolata var. flava as "lanceolate or narrowly oblong, several times longer than broad" and those of C. lanceolata (represented by var. chrysantha) as "broadly elliptic to ovate, (1)1.5-2.5(4) cm long, usually over 1/3 as broad." Our study showed that the leaves of C. lanceolata var. flava average approximately seven times longer than wide, while those of typical C. lanceolata average three times as long as wide (Table 2). These numeric differences are in accordance with the earlier, largely qualitative leaf shape differences described for these taxa.

Historically, it is interesting to note that Rydberg (1922) recognized the patterns in leaf venation that distinguish the narrow-leaved Claytonias (i.e., C. virginica, C. rosea, and C. multiscapa) from C. lanceolata. He observed that the former group has leaves "1-ribbed or indistinctly 3-ribbed," while the latter taxon has leaves that are "distinctly triple-ribbed." Our results uphold this as a valid and important means of distinguishing the narrow-leaved Claytonia populations from those of typical C. lanceolata in the northern Rocky Mountains; the leaves of C. lanceolata var. flava have only one distinct vein (the midvein), while populations of typical C. lanceolata have leaves with two prominent lateral veins in addition to the midvein (Table 4).

Davis (1952) also distinguished C. lanceolata var. flava from typical C. lanceolata by petal apex outline, describing the former as having petals "rounded at the apex," and the latter with petals "retuse or emarginate." Our studies confirmed that the petals of C. lanceolata var. flava are rounded at the apex, while those of typical C. lanceolata are usually retuse or emarginate (Table 4). In addition, the results of both the field and morphological studies confirmed that the petals of C. lanceolata var. flava are more nearly oval in shape, while those of C. lanceolata are most often obovate, and frequently narrowly so. These results also concur with the descriptions by Davis (1952).

In addition to the morphological analyses, isozyme electrophoresis also clearly indicated that C. lanceolata var. flava is specifically distinct from typical C. lanceolata. The mean genetic identity between the latter species and populations representing C. lanceolata var. flava (0.69 -- WILL NEED TO REVISE) is close to the mean between congeneric species (0.67) presented in several reviews (Crawford 1983; Gottlieb 1981).

Secondly, the results of our studies revealed that the diploid represented by populations assignable to C. lanceolata var. flava includes conspecific yellow- and white-flowered plants. In this and other cases, flower

color has been found to be of limited use in delineating natural taxonomic relationships within the genus. Elsewhere in North America, several other predominantly white- or pink-flowered taxa in Claytonia include named or unnamed yellow-flowered forms. Examples include C. lanceolata var. chrysantha (Douglas and Taylor 1972), C. virginica L. var. hammondiae (Kalmbacher) Doyle, Lewis and Snyder (Snyder 1992), and a recently discovered population of C. caroliniana Michaux in Maryland that contains yellow-flowered plants in addition to typical white- to pink-flowered plants (Snyder 1992). Such color forms are probably best viewed as minor variants within their respective taxa. They probably do not typically warrant taxonomic recognition, except in cases where their populations are correlated with ecological, genetic, geographic, and/or further morphological segregation (as is the case for C. virginica var. hammondiae) (Snyder 1992). In the case of C. lanceolata var. chrysantha, Douglas and Taylor (1972) found that, based on morphological, ecological, and biochemical analyses, "...there is no significant difference between the yellow and white forms of Claytonia lanceolata, other than petal color," and that "(t)he difference in petal color is most likely due to one or very few genes, as evidenced by the virtual lack of intermediate color forms." They concluded that "...there is no basis for the recognition of var. chrysantha..." (Douglas and Taylor 1972). The results of our studies indicate the

same situation with respect to the yellow and white flower color phenotypes of "C. lanceolata var. flava." Plants of the two color phenotypes are biotically sympatric in at least four populations in the northern Rocky Mountains, and these phenotypes reflect little or no morphological or isozyme differentiation within or among those populations. While there was some genetic differentiation among populations of C. lanceolata var. flava, plants of the two flower color phenotypes are "contaxonomic"; at the four sites where they are biotically sympatric, individuals of the two phenotypes are nearly or completely identical genetically. This suggests that in such cases they are part of the same breeding population, that flower color represents simple genetic differences (i.e., determined by one or a few genes), and that flower color does not warrant taxonomic recognition in this diploid.

Lastly, the herbarium morphological study revealed a strong similarity between C. rosea and C. lanceolata vars. flava and multiscapa (Fig. 3). The latter variety, all collections of which are white-flowered, is reported by Hitchcock et al. (1964) as occurring in "Yellowstone National Park and vicinity." The morphological similarity of var. multiscapa to var. flava, and its complete geographic overlap with stations of white- and/or yellow-flowered populations of the latter entity, support the notion that var. multiscapa represents the same taxon as the

white-flowered form of var. "flava." Claytonia rosea probably represents more southerly, white- to pink-flowered populations of the same narrow-leaved taxon as well. Like the populations of C. lanceolata var. flava sampled in Montana and Wyoming, numerous Colorado populations of C. rosea are diploid (n = 8; Halleck and Wiens 1966).

In summary, electrophoretic and morphological data clearly revealed that C. lanceolata var. flava does not belong in the C. lanceolata complex. Rather, its affinities lie with the narrow-leaved group of species that includes C. rosea, C. tuberosa and C. virginica. On the basis of the herbarium study, C. lanceolata vars. flava and multiscapa would best be treated as synonyms of C. rosea, until the relationship of the latter to C. tuberosa (a white-flowered species of the Yukon, Alaska and Siberia; Miller 1992) is more fully evaluated. Further analysis may indicate that C. rosea and C. lanceolata vars. flava and multiscapa should all be included in C. tuberosa as members of a wide-ranging taxon, the latter name having nomenclatural priority (J. Miller, pers. comm.). Formal nomenclatural changes are not made here, but left for upcoming publication of a complete revision of the genus (Miller 1992).

Conservation Status. In the northern Rocky Mountains, narrow-leaved populations of Claytonia consisting wholly or partially of yellow-flowered individuals remain uncommon

(ten such populations are now known from Idaho, Montana and Wyoming). However, the conspecific narrow-leaved, white-flowered populations are more common and widespread. These white-flowered populations occur over a larger area in northwestern and north-central Wyoming, and south-central to southwestern Montana. Populations of both flower color phenotypes are usually very large in size and areal extent, and at least 30 populations consisting of one or both forms have now been documented in Montana (Montana Natural Heritage Program, Helena). Because the yellow and white flower color phenotypes are conspecific, C. lanceolata var. flava is not in need of protective listing, regardless of its eventual taxonomic disposition; it should be removed from further consideration for federal listing as a threatened or endangered plant. This conclusion is further substantiated by the observation that this taxon appears to be conspecific with C. rosea.

When necessary, protection of endangered plant taxa should be preceded by evaluation of their taxonomic status. In the case of C. lanceolata var. flava, modern systematic techniques have proven invaluable for this purpose. These techniques will be increasingly useful in ensuring that the limited funds available for endangered species conservation are devoted to taxonomically deserving taxa and the maintenance of genetic diversity.

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TABLE 1. Populations of *Claytonia lanceolata* vars. *flava* and *lanceolata* analyzed in isozyme and field morphological studies. Flower color phenotypes of var. *flava* were sampled as separate "populations" where they are biotically sympatric (Anaconda, Champion, Vipond, and Wyoming). Vouchers are deposited at MONTU; numbers marked with * have duplicates deposited at OSC. + = the Burton Park population of white-flowered *flava* was not included in the electrophoretic study.

Taxon	Abbreviation	Collection data
C. l. var. *flava*		
	ANACON WHITE	Montana, Deer Lodge Co. Shelly & Lesica 1412*
	ANACON YELLOW	Montana, Deer Lodge Co. Shelly & Lesica 1413*
	BOULDER WHITE	Montana, Sweet Grass Co. Shelly 1617
	BURTON PARK WHITE+	Montana, Silver Bow Co. Shelly, Schassberger & Schitoskey 1504
	CHAMPION YELLOW	Montana, Jefferson Co. Shelly 1417*
	CHAMPION WHITE	Montana, Jefferson Co. Shelly & Lesica 1423*
	HEBGEN YELLOW	Montana, Gallatin Co. Shelly & Lesica 1419*
	VIPOND YELLOW	Montana, Beaverhead Co. Shelly & Scow 1444*
	VIPOND WHITE	Montana, Beaverhead Co. Shelly & Scow 1445*
	WYOMING YELLOW	Wyoming, Fremont Co. Shelly & Lesica 1446*
	WYOMING WHITE	Wyoming, Fremont Co. Shelly & Lesica 1447*
C. l. var. *lanceolata*		
	ANACON LANCEOL	Montana, Deer Lodge Co. Shelly & Lesica 1411
	CHAMPION LANCEO	Montana, Jefferson Co. Shelly & Lesica 1422
	HEBGEN LANCEOL	Montana, Madison Co. Shelly & Lesica 1420*
	VIPOND LANCEOL	Montana, Beaverhead Co. Shelly 1201
	WYOMING LANCEOL	Wyoming, Teton Co. Shelly & Lesica 1448*

TABLE 2. Taxon means, ranges and standard deviations for field morphological data, *Claytonia lanceolata* vars. *flava* and *lanceolata*.

	yellow flava	white flava	lanceolata
No. of accessions	225	270	225
Height (cm)			
Mean	7.6	9.6	4.1
Range	3.5-16.9	4.0-27.2	1.4-10.8
s.d.	2.1	1.3	1.5
Leaf length (mm)			
Mean	36.0	42.8	26.3
Range	13.0-76.0	14.0-111.0	14.0-46.0
s.d.	11.7	18.4	6.8
Leaf width (mm)			
Mean	5.4	5.9	9.1
Range	2.5-11.5	3.0-13.5	4.0-19.0
s.d.	1.6	1.9	2.7
Sepal length (mm)			
Mean	5.0	5.1	4.0
Range	3.0-8.5	3.5-8.0	2.0-6.0
s.d.	0.98	0.83	0.79
Petal width (mm)			
Mean	5.3	5.7	4.2
Range	3.0-8.5	3.0-9.0	2.5-9.0
s.d.	0.96	0.97	0.84
Petal length (mm)			
Mean	8.6	9.2	8.8
Range	6.0-12.0	6.5-13.5	4.5-12.5
s.d.	1.2	1.1	1.3
Leaf length/width			
Mean	6.8	7.5	3.0
Range	3.3-14.2	2.6-18.5	1.6-6.3
s.d.	2.0	2.6	0.9
Petal length/width			
Mean	1.7	1.6	2.1
Range	1.1-2.3	1.1-2.3	0.5-3.0
s.d.	0.2	0.2	0.3

TABLE 3. Loadings of the first two principal components for the quantitative characters measured in the field morphology studies.

Characteristics	Component 1	2
Petal width	0.832	0.114
Leaf length	0.807	0.177
Height	0.789	0.033
Leaf length/width	0.755	-0.426
Sepal length	0.700	0.202
Petal length/width	-0.646	0.395
Leaf width	-0.189	0.847
Petal length	0.474	0.702

TABLE 4. Taxon means, ranges and standard deviations for quantitative and qualitative morphological characters from herbarium specimens, Claytonia lanceolata vars. flava, lanceolata, and multiscapa, and C. rosea. For some characters, the number of accessions was less than that shown in the first line; exceptions are given in parentheses after the means.

	flava	lanceolata	multiscapa	rosea
No. of accessions	17	124	8	35
Leaf length (mm)				
Mean	41.6	32.6	43.4	44.0
Range	18-71	13-59	29-56	17.5-84
s.d.	3.1	0.9	3.7	2.8
Leaf width (mm)				
Mean	5.2	10.4	5.9	5.1
Range	2.4-8.4	2.8-26	2.3-10.6	1.3-14
s.d.	0.4	0.4	1.1	0.5
Leaf length/width ratio				
Mean	8.3	3.5	8.7	10.8
Range	4.7-15.1	1.7-12.5	5.2-13.0	4.0-32.8
s.d.	0.6	0.1	1.2	1.2
Sepal length (mm)				
Mean	4.4	3.8	4.8	4.7
Range	3.3-5.7	2.0-6.6	4.0-5.9	2.9-7.0
s.d.	0.2	0.1	0.3	0.2
Petal width (mm)				
Mean	4.3	4.0 (123)	4.6	4.1 (32)
Range	3.0-5.4	1.8-6.2	2.9-6.0	2.7-5.5
s.d.	0.2	0.1	0.3	0.1
Petal length (mm)				
Mean	9.5	9.1	9.2	9.3 (34)
Range	6.8-11.8	5.2-14.0	7.5-11.3	5.8-12.7
s.d.	0.3	0.1	0.6	0.3
Petal length/width ratio				
Mean	2.3	2.4 (123)	2.1	2.3 (32)
Range	1.5-3.1	1.6-3.7	1.3-2.6	1.5-3.2
s.d.	0.1	0.1	0.2	0.1
Petal/sepal length ratio				
Mean	2.2	2.4	1.9	2.1 (34)
Range	1.6-2.8	1.2-3.7	1.3-2.5	1.2-3.7
s.d.	0.1	0.1	0.1	0.1
Petal apex outline*				
Mean	0.9 (16)	0.1 (118)	1.0	0.9
Leaf venation**				
Mean	0.0	0.9 (123)	0.1	0.1 (34)

*Petal apex outline scores:
0 - retuse/emarginate
1 - rounded

**Leaf venation scores:
0 - lateral veins inconspicuous or absent
1 - lateral veins conspicuous

TABLE 5. Loadings of the first two principal components for the quantitative and qualitative characters used in the herbarium morphology study.

	Component	
Characteristics	1	2
Venation	-0.840	0.039
Petal apex outline	0.830	-0.051
Leaf length/width	0.775	-0.061
Leaf width	-0.630	0.472
Petal/sepal ratio	-0.607	0.121
Sepal length	0.588	0.450
Petal width	0.069	0.872
Petal length	-0.095	0.778
Leaf length	0.344	0.500
Petal length/width	-0.174	-0.409